

# DUNE Costing

Gina Rameika

NCG Kick-off Meeting

16 October 2019

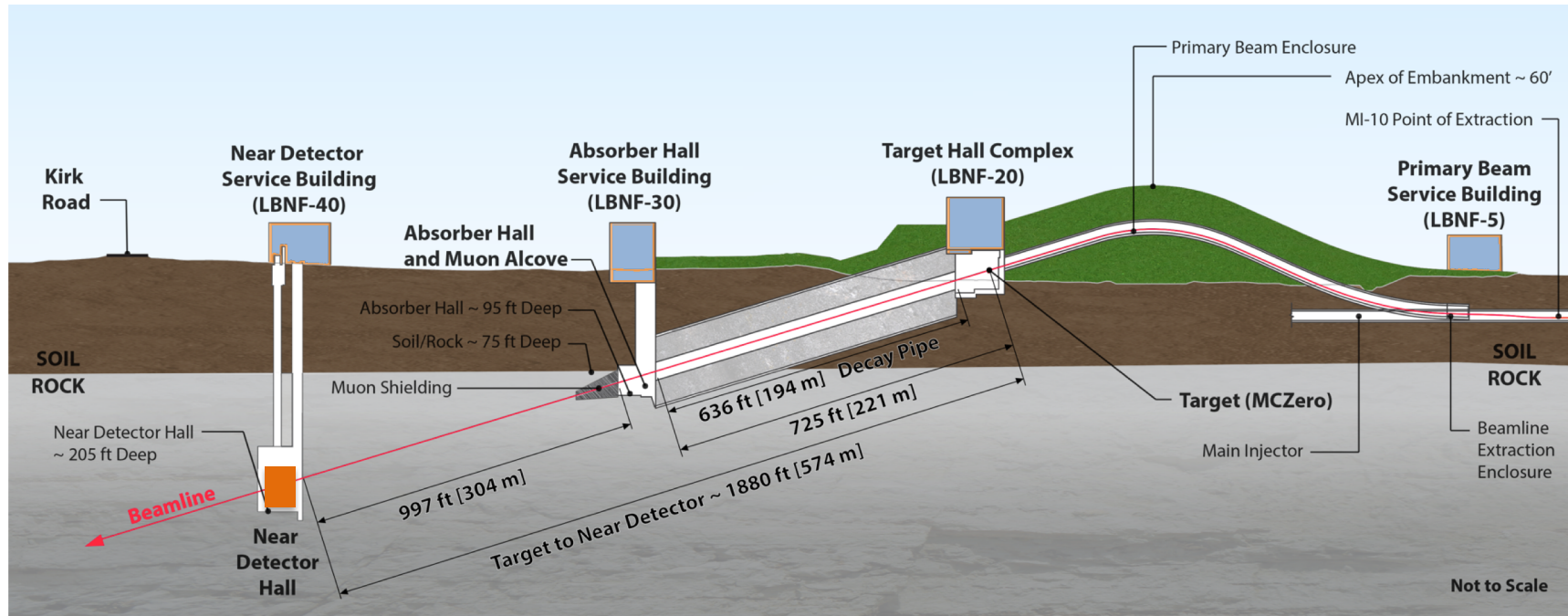
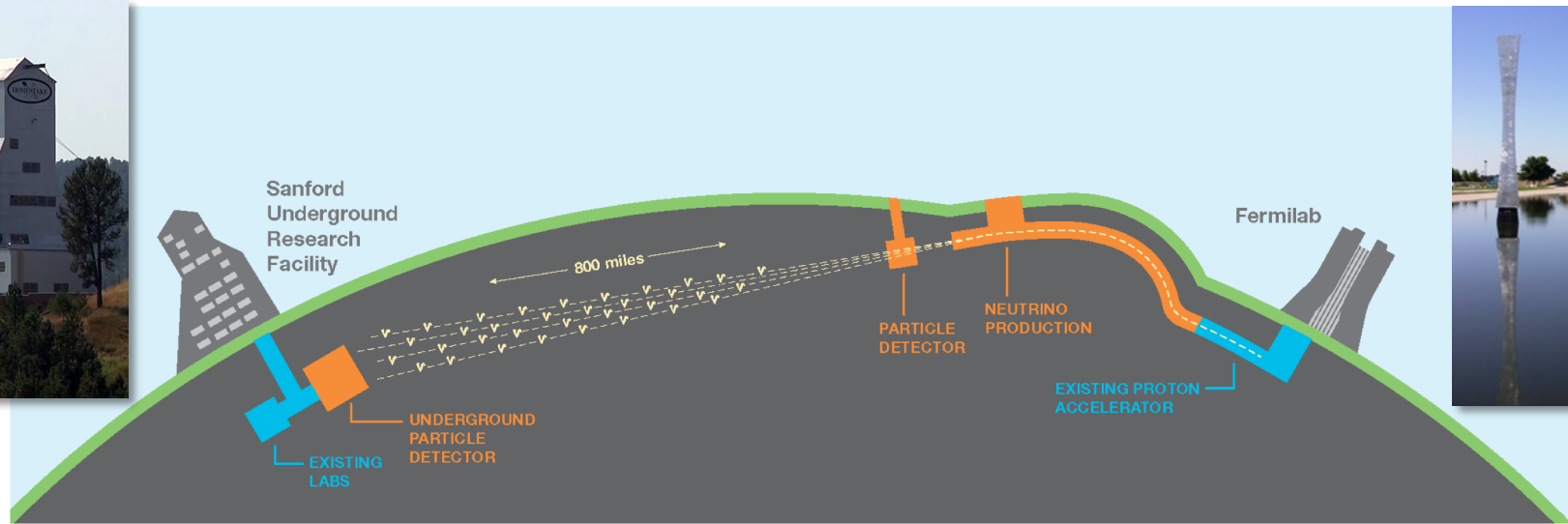
# Who am I?

- Scientist at Fermilab since 1982
- Worked on :
  - Fixed Target : Hyperons, Neutrinos (DONUT) ('80s & '90s)
  - Deputy Head of Research Division (mid '90s)
  - NuMI/MINOS Project management (late '90s)
  - Soudan Laboratory Operations Manager for Fermilab (2004-2008)
  - Co-leader of Future Long Baseline Study (2006 – 2007)
  - LBNE Project (2008 – 2011)
  - MicroBooNE Project Manager (2011 – 2015)
  - Neutrino Division Head (2014 – 2016)
  - ProtoDUNE-SP Construction Coordinator (2016 – 2018)
  - DUNE Resource Coordinator (2019 - )

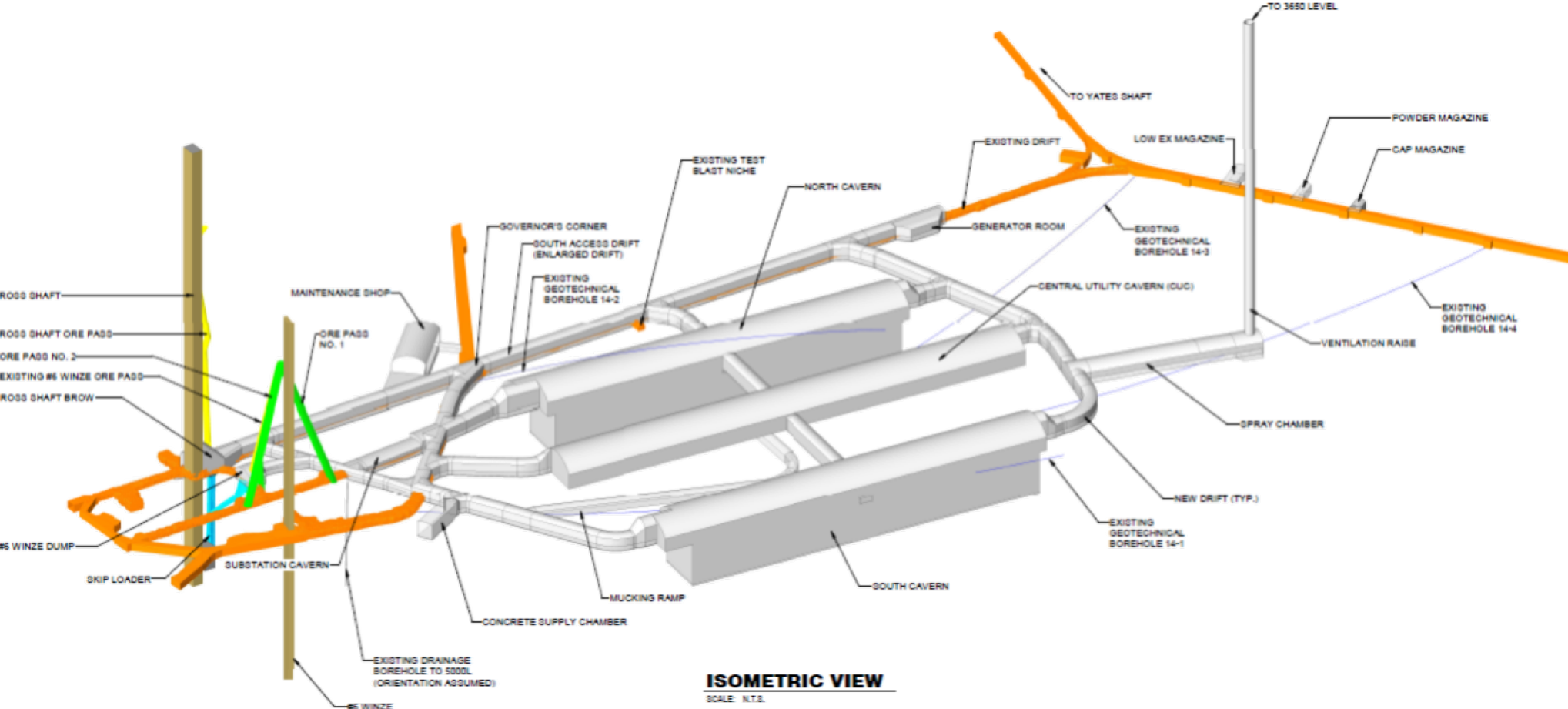
# Outline for Today

- DUNE Overview and Organization
- The DUNE Far Detector Single Phase Module
  - High Voltage : Cathode Planes and Field Cages
  - Anode Plane Assemblies
  - TPC Electronics (cold and warm)
  - Photon Detectors
  - Data Acquisition
  - Instrumentation and Calibration
- Consortia Cost Books
- Cost Book Rollup
- Resource Matrix
- Next Steps

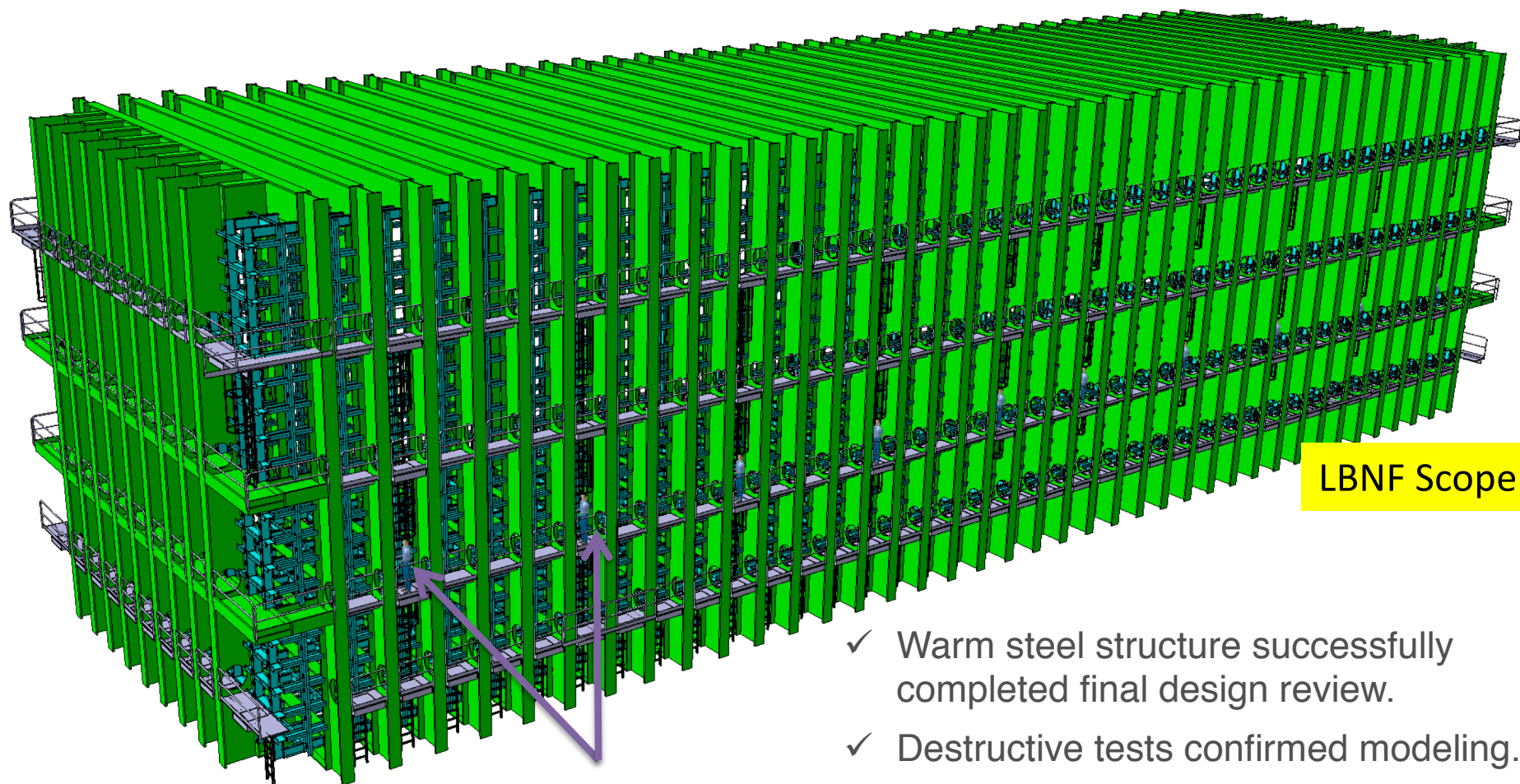
# DUNE Overview



# Far Site – Detector Caverns



# Free-Standing Steel Cryostat Design



LBNF Scope

People for Scale

- ✓ Warm steel structure successfully completed final design review.
- ✓ Destructive tests confirmed modeling.
- ✓ Membrane design by GTT for SP detector completed.

Designed and  
engineered  
by

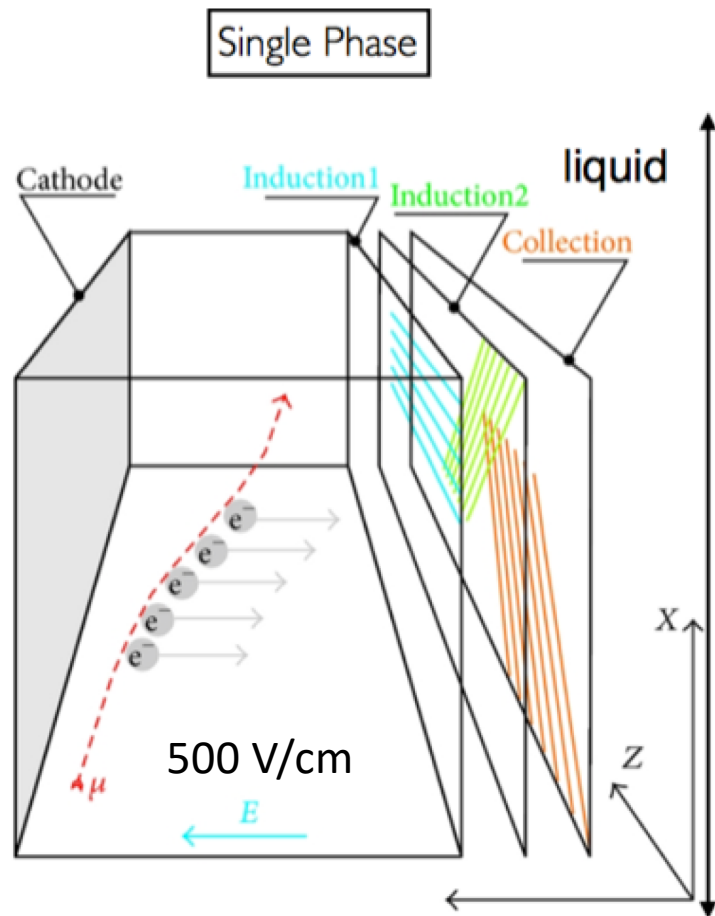


## External Dimensions

62.7' W x 59' H x 216.5' L (19.1m W x 18.0m H x 66.0m L)

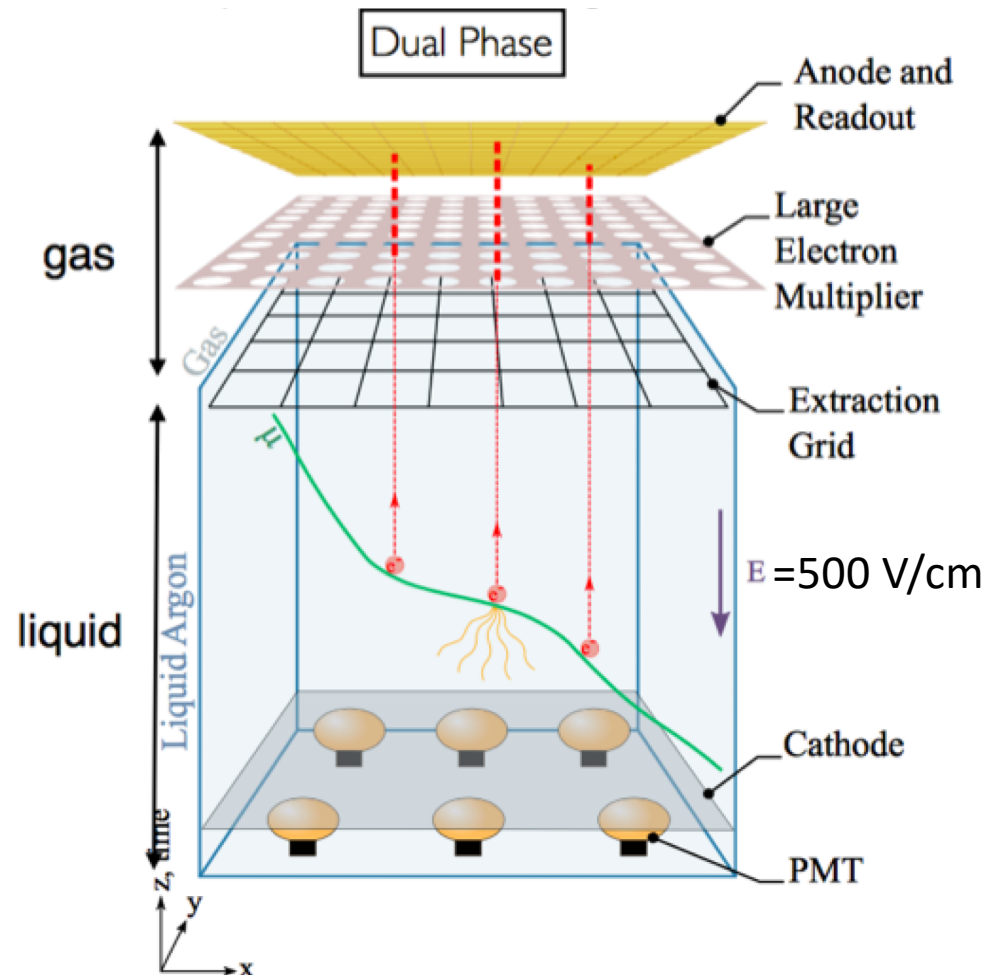
# DUNE Detector Technologies

- Ionization charges drift horizontally and are read out with wires
- No signal amplification in liquid
- 3.5 m maximum drift



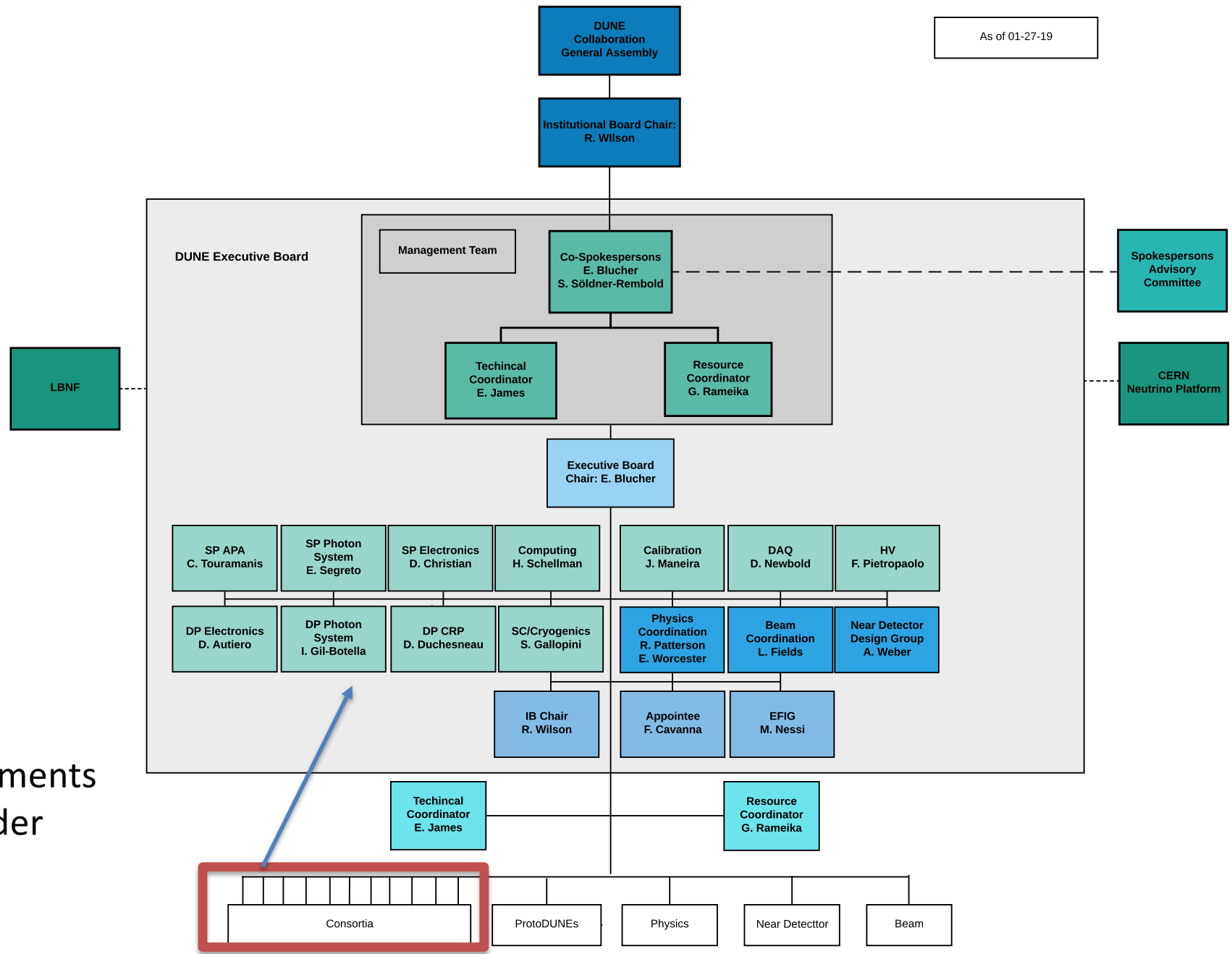
16 19 Sep 2019 RRB Meeting

- Ionization charges drift vertically and are read out on PCB anode
- Amplification of signal in gas phase by LEM
- 12 m maximum drift



# Collaboration Management

As of 01-27-19



Appointments now under review



# Far Detector Consortia

## Single-Phase

- APA: Christos Touramanis (Liverpool)
- Photon Detection System: Ettore Segreto (Campinas)
- TPC Electronics: Dave Christian (FNAL)



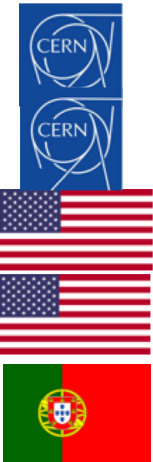
## Dual-Phase

- CRP: Dominique Duchesneau (LAPP)
- Photon Detection System: Ines Gil Botella (CIEMAT)
- TPC Electronics: Dario Autiero (IPNL)

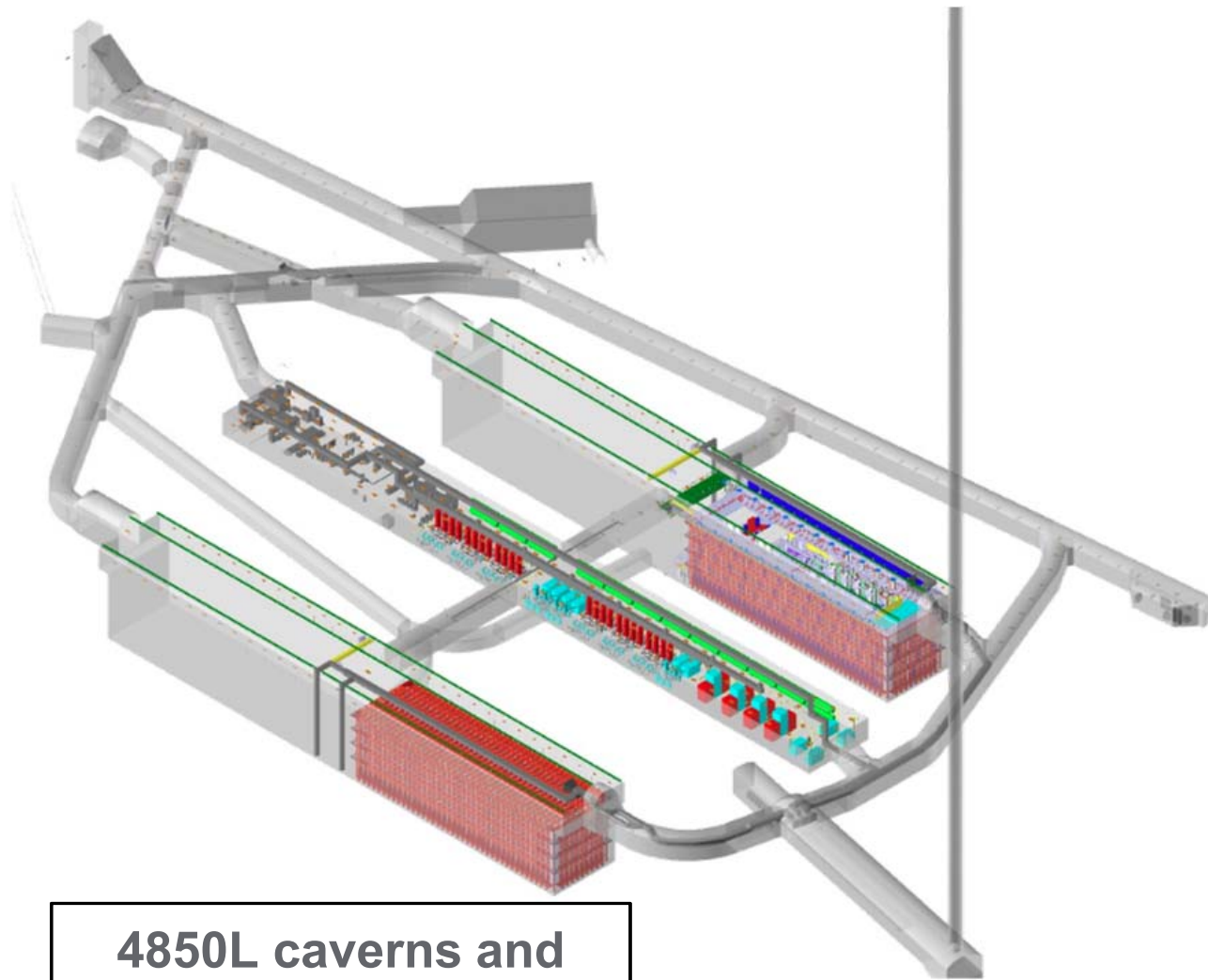


## Joint SP/DP

- HV System: Francesco Pietropaolo (CERN)
- DAQ: Giovanna Lehmann Miotto (CERN)
- Slow Controls/Instrumentation: Sowjanya Gollapinni (Tennessee)
- Computing: Heidi Schellman (Oregon State)
- Calibration: Jose Maneira (LIP)



# DUNE Single Phase Far Detectors at SURF

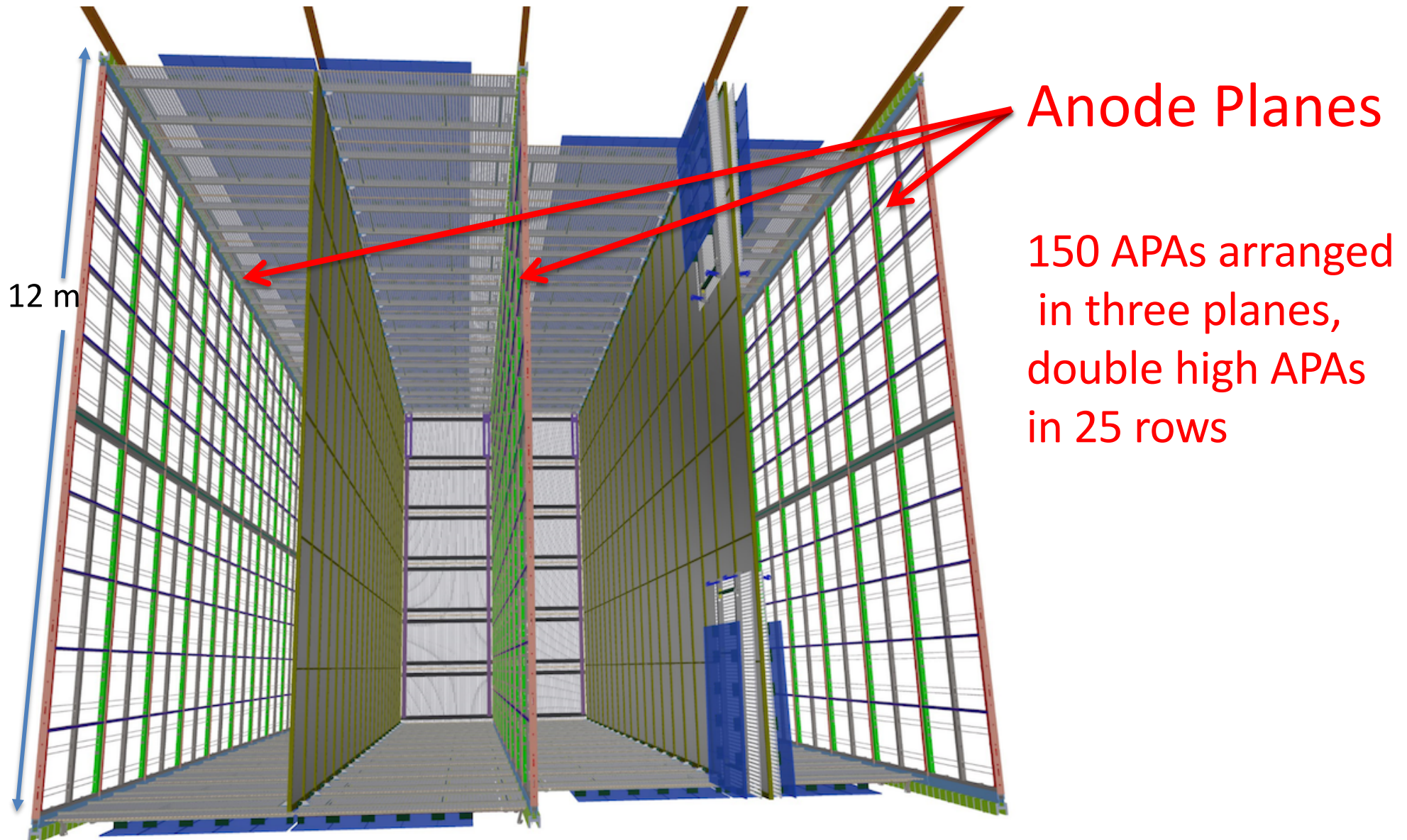


4850L caverns and drift layout

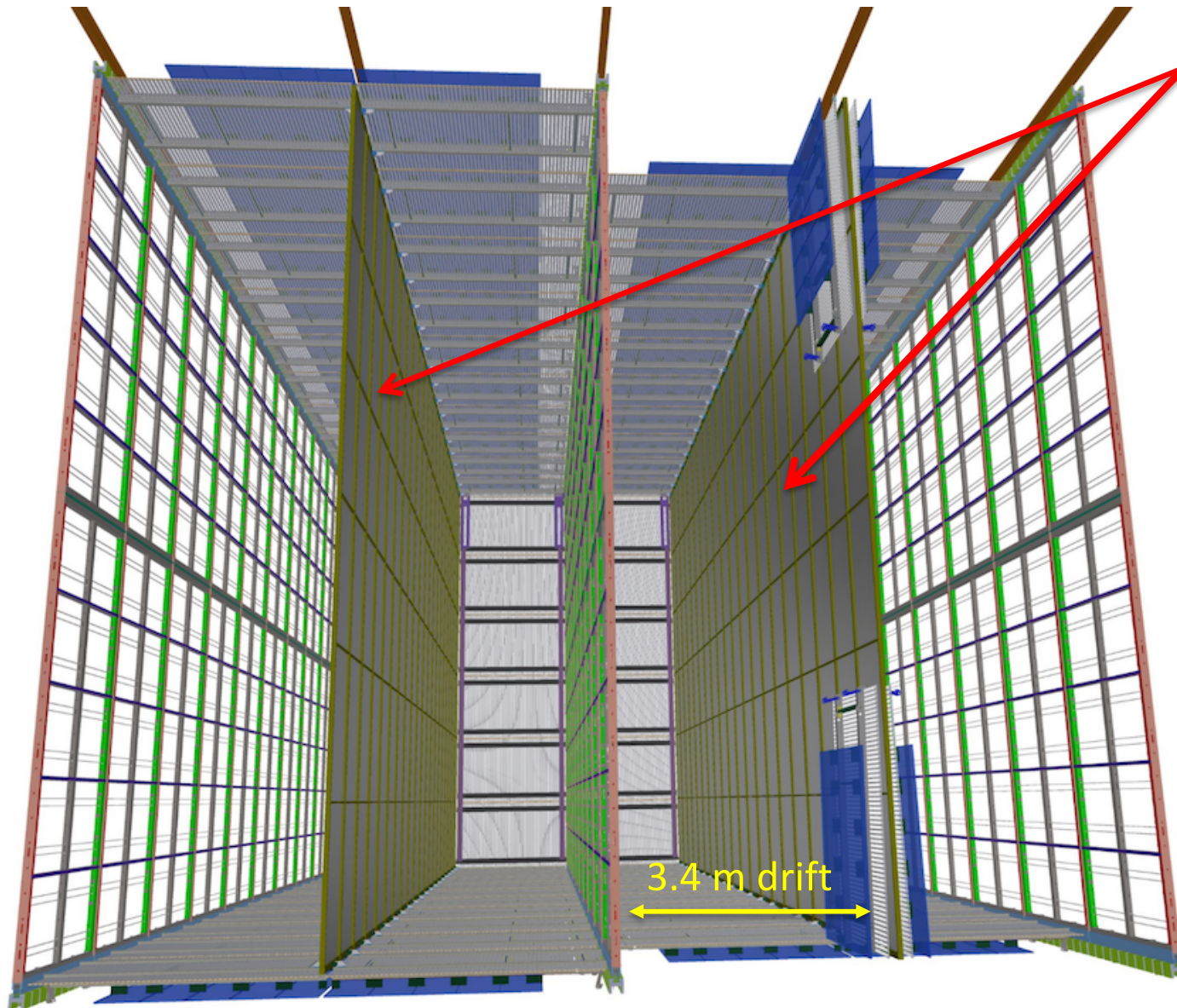
# Components

- **Drift ionization charge** : High Voltage
  - HV power supply and feed-through
  - Cathode Plane
  - Field Cages
    - Resistive dividers
- **Collect ionization charge** : Sense wires, electronics
  - Anode Planes
  - Front-end amplification, digitization, readout
- **Collect scintillation light** : wavelength shifters, light guides, light collection electronics
  - Photon detector modules with SiPM readout
- Data Acquisition
- Instrumentation and Calibration systems

# The DUNE Single Phase Module



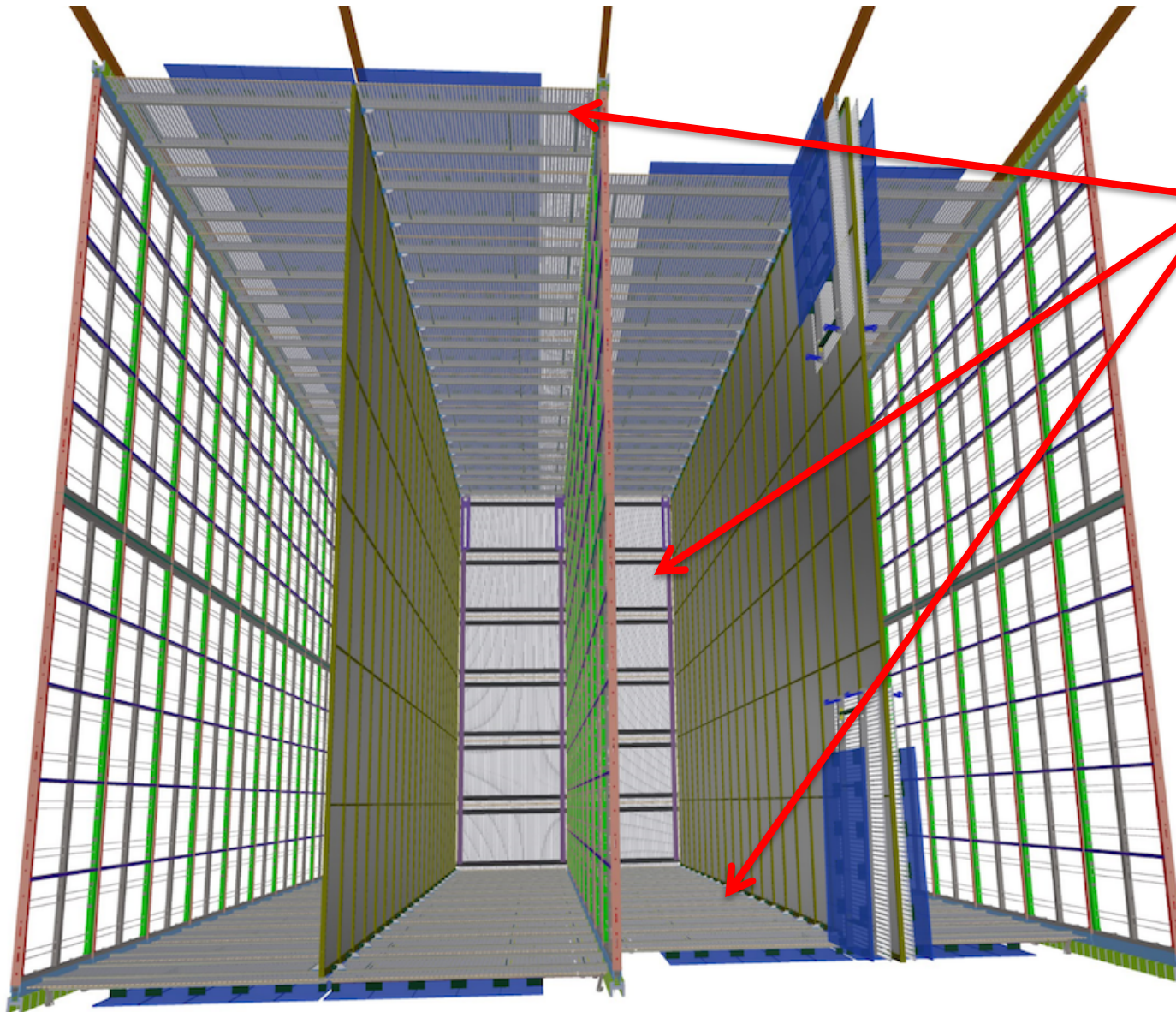
# The DUNE Single Phase Module



**High Voltage  
Cathode Planes**

2 cathode planes  
each composed of  
150 1.2m w x 4m h  
CPA modules

# The DUNE Single Phase Module



**Field Cages :**

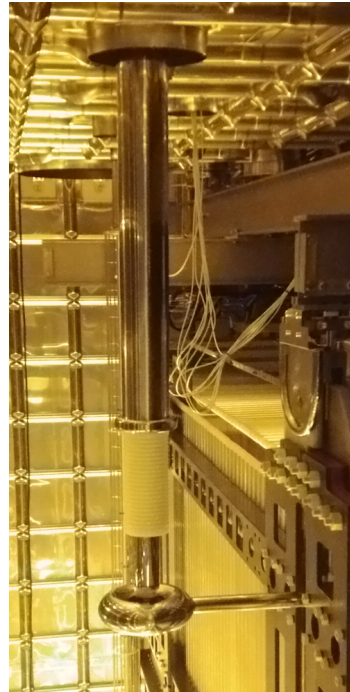
**Top, Bottom and  
Endwalls**

100 T and B modules  
48 Endwall modules

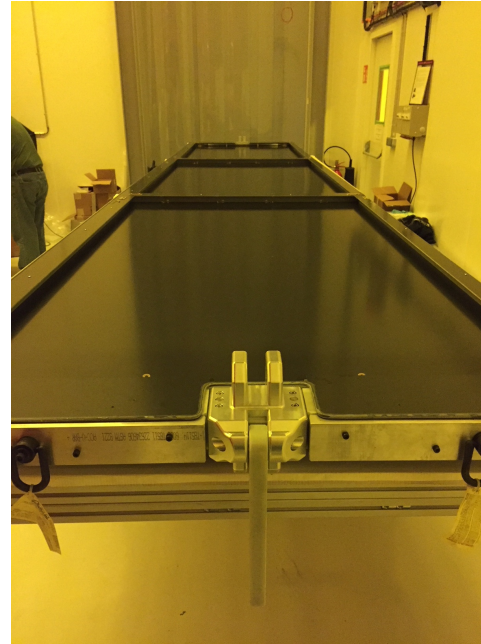
# High Voltage System Components



Power Supply



Feed-through



US-DOE, CERN, INFN

CPA Panel (from PD)  
DUNE will be  
2X longer

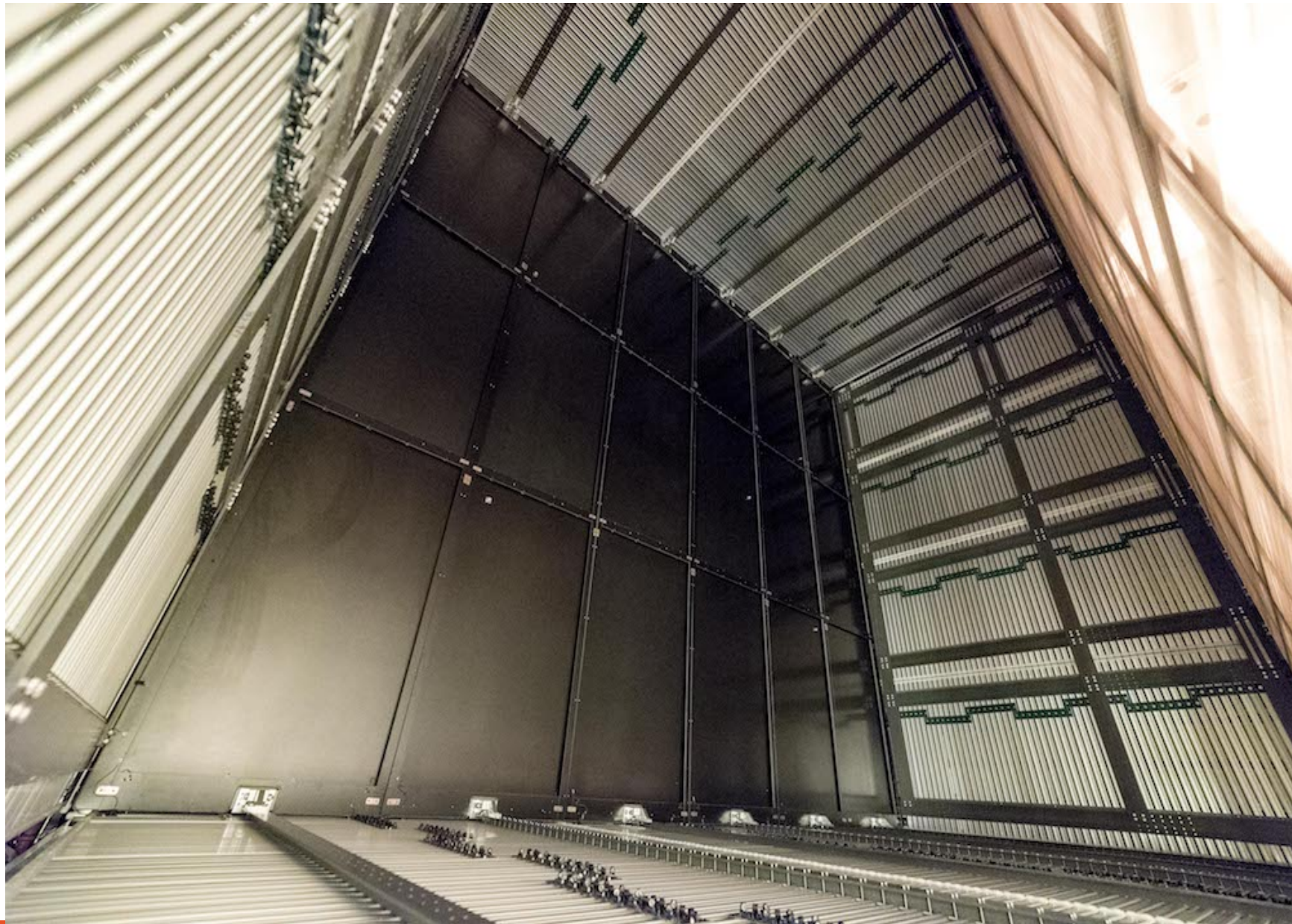
Top/bottom Field  
Cage module  
with Ground plane

Resistor Dividers

End-wall



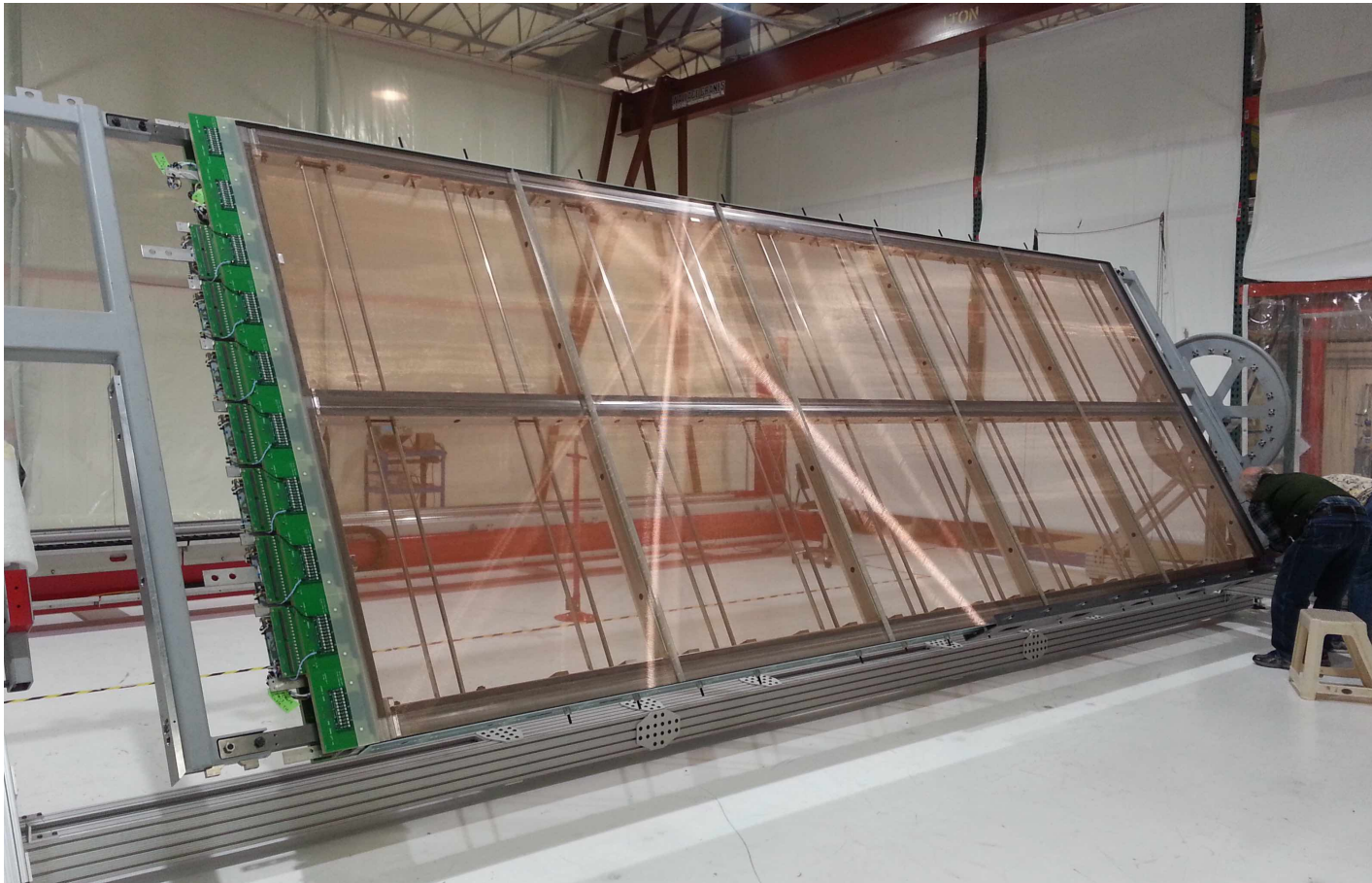
# High voltage drift volume in PD





# Anode Plane Assemblies

UK - 150  
US-NSF - 150



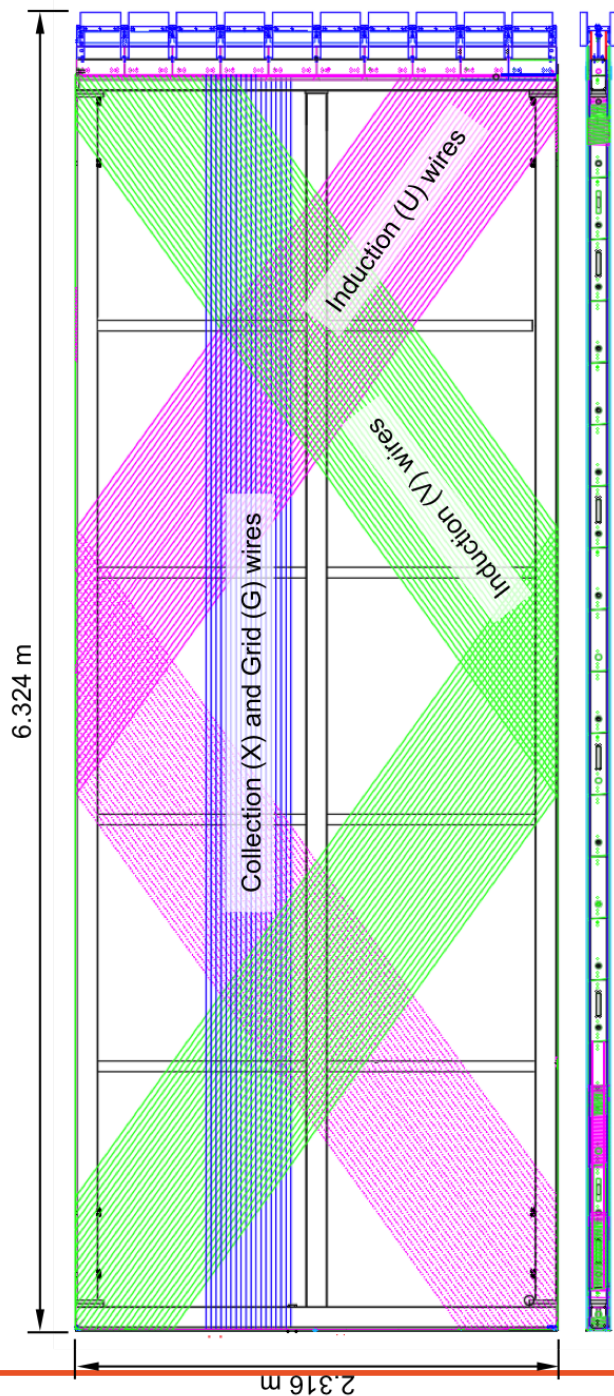


Table 1.3: APA design parameters

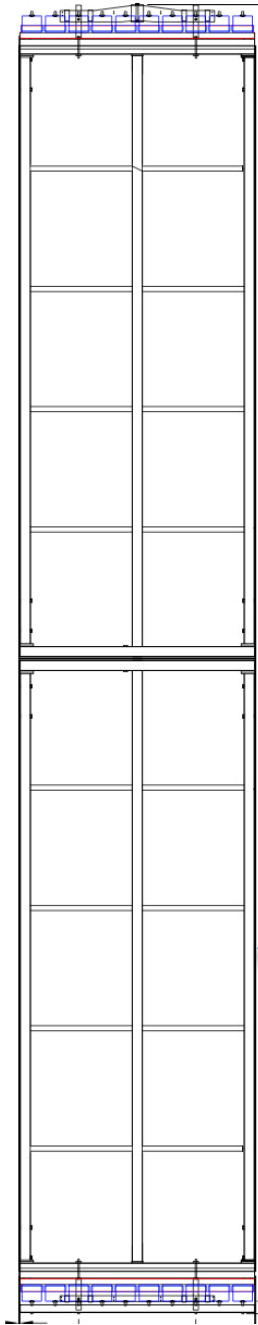
Parameter	Value
Active height	5.984 m
Active width	2.300 m
Wire pitch ( $U, V$ )	4.669 mm
Wire pitch ( $X, G$ )	4.790 mm
Wire pitch tolerance	$\pm 0.5$ mm
Wire plane spacing	4.75 mm
Wire plane spacing tolerance	$\pm 0.5$ mm
Wire Angle (w.r.t. vertical) ( $U, V$ )	$\pm 35.7^\circ$
Wire Angle (w.r.t. vertical) ( $X, G$ )	$0^\circ$
Number of wires / APA	960 ( $X$ ), 960 ( $G$ ), 800 ( $U$ ), 800 ( $V$ )
Number of electronic channels / APA	2560
Wire material	beryllium copper
Wire diameter	150 $\mu\text{m}$

Anode Plane	Bias Voltage
$G$ - Grid	-665 V
$U$ - Induction	-370 V
$V$ - Induction	0 V
$X$ - Collection	820 V
Grounding Mesh	0 V

Drift



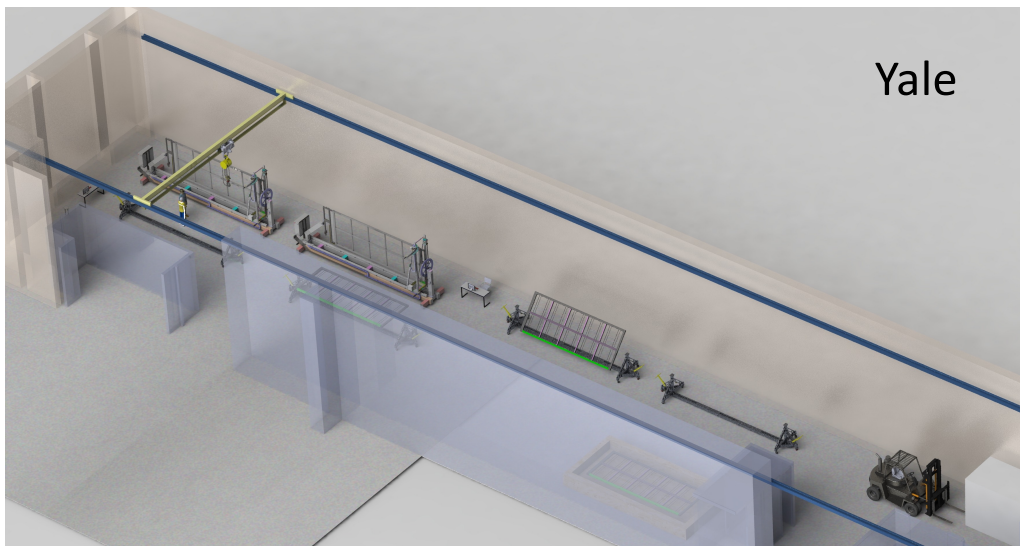
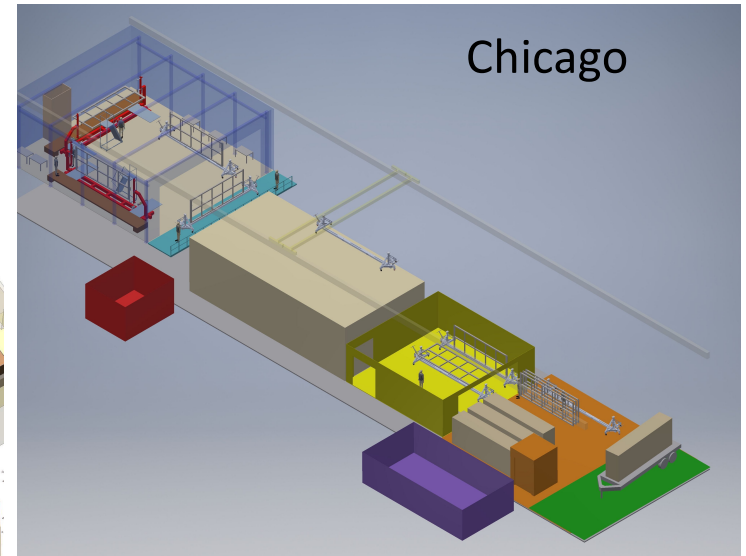
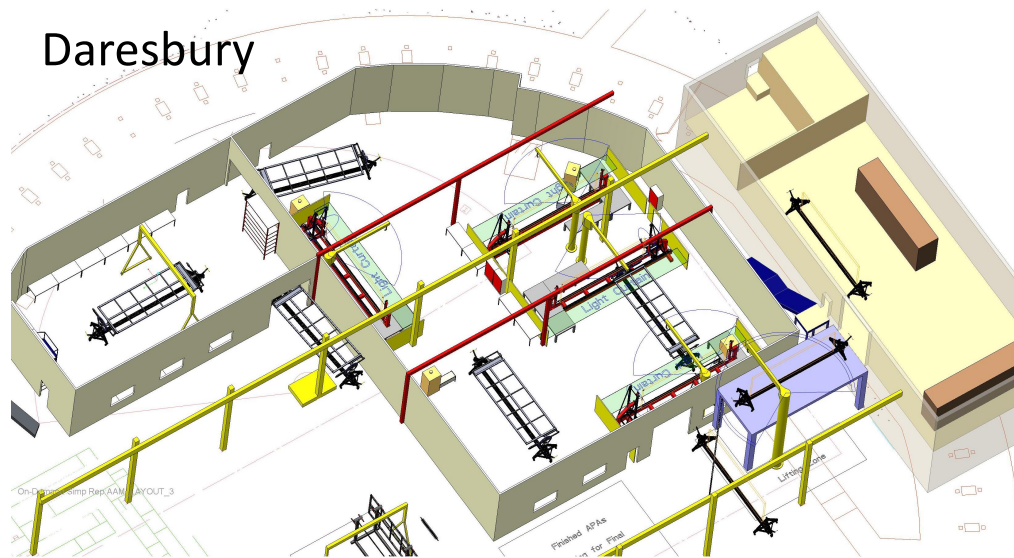
Table 1.2: Baseline bias voltages for APA wire layers.



- Two APA's are stacked vertically, joined at the "feet"
- Production
  - 150 produced in UK, 150 in US
  - UK Factory at Daresbury Lab
    - 4 winding machines
  - US Production Sites : Chicago, Yale and PSL(Wisc)
    - 2 winding machines each at Chicago, Yale, PSL

This one hangs upside down

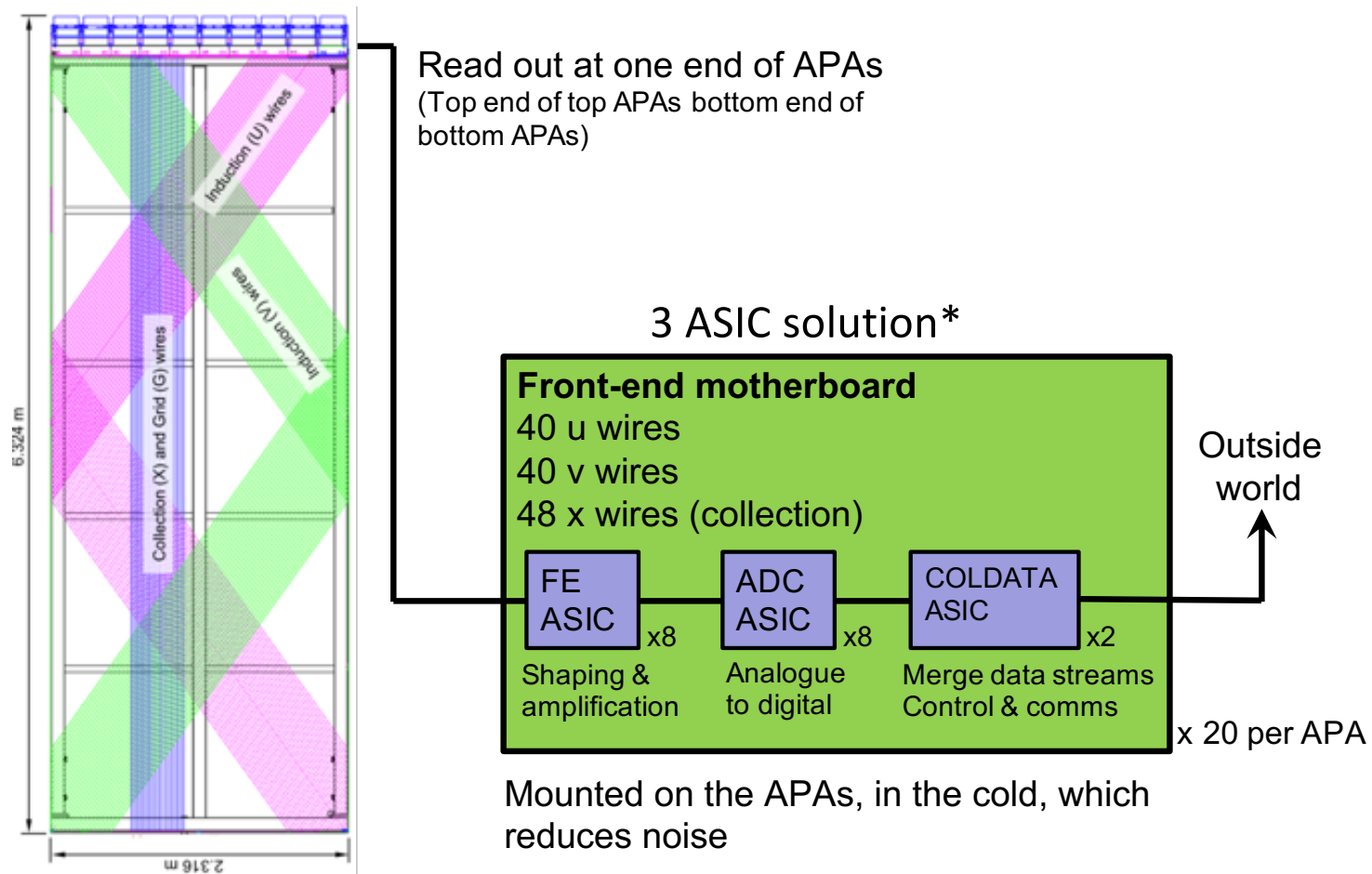
# APA Factory layouts



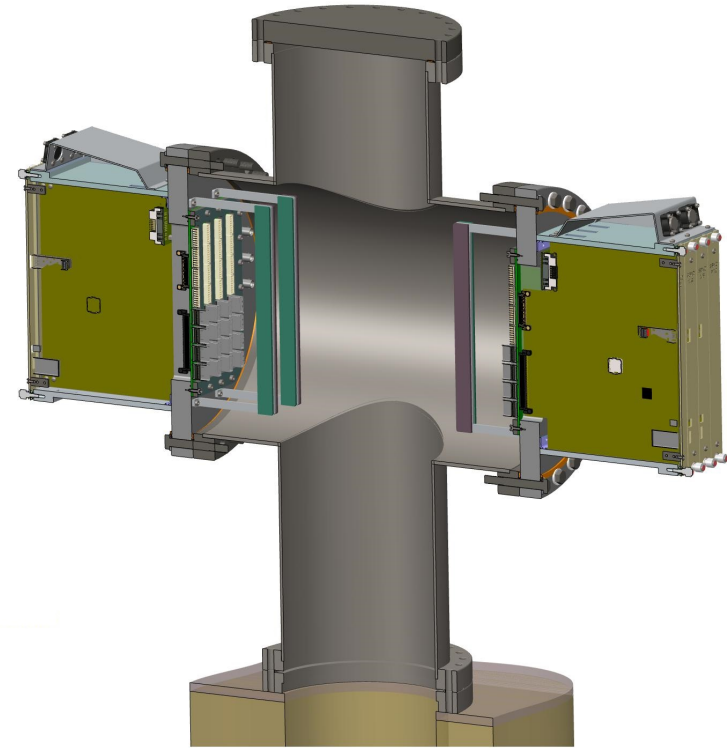
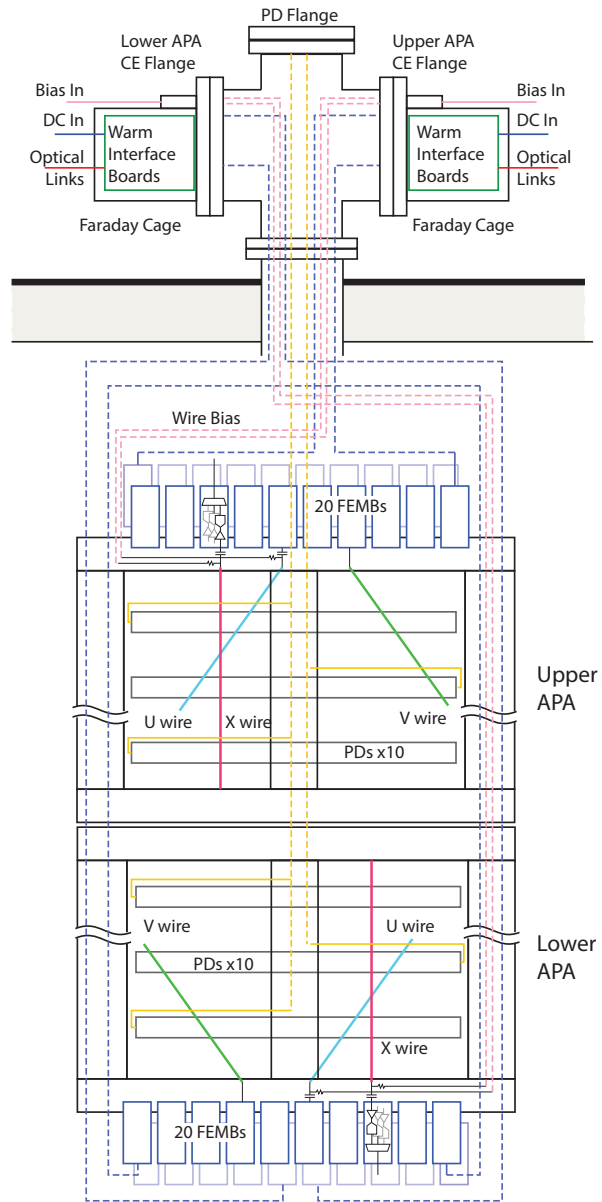
# TPC Electronics

100% DOE Scope

- 2560 electronics channels (wires) per APA
- 128 channels per FE ASIC -> 20 COLD mother boards per APA
- 3000 mother boards per Single Phase module

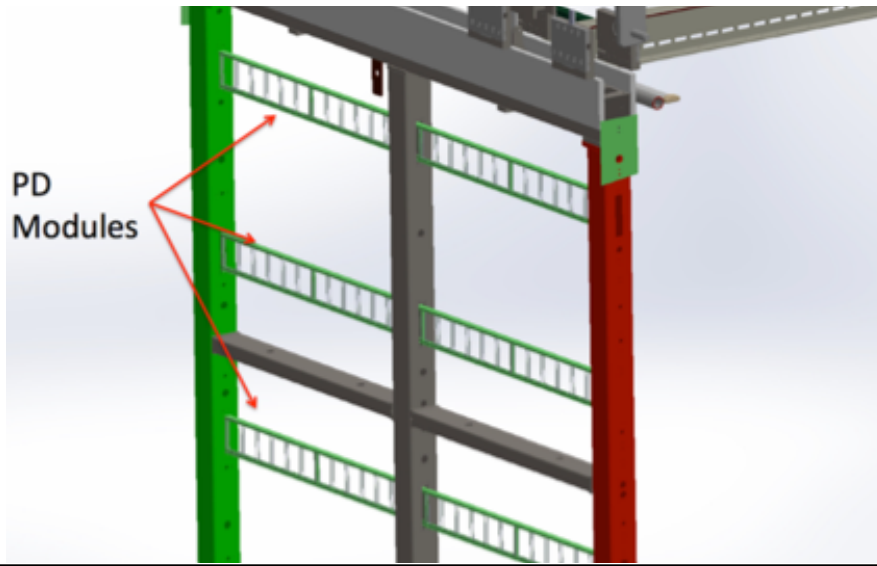


# Cold cables to warm electronics



1 Feed-through per APA pair  
5 WIBs per APA

# Photon Detector System

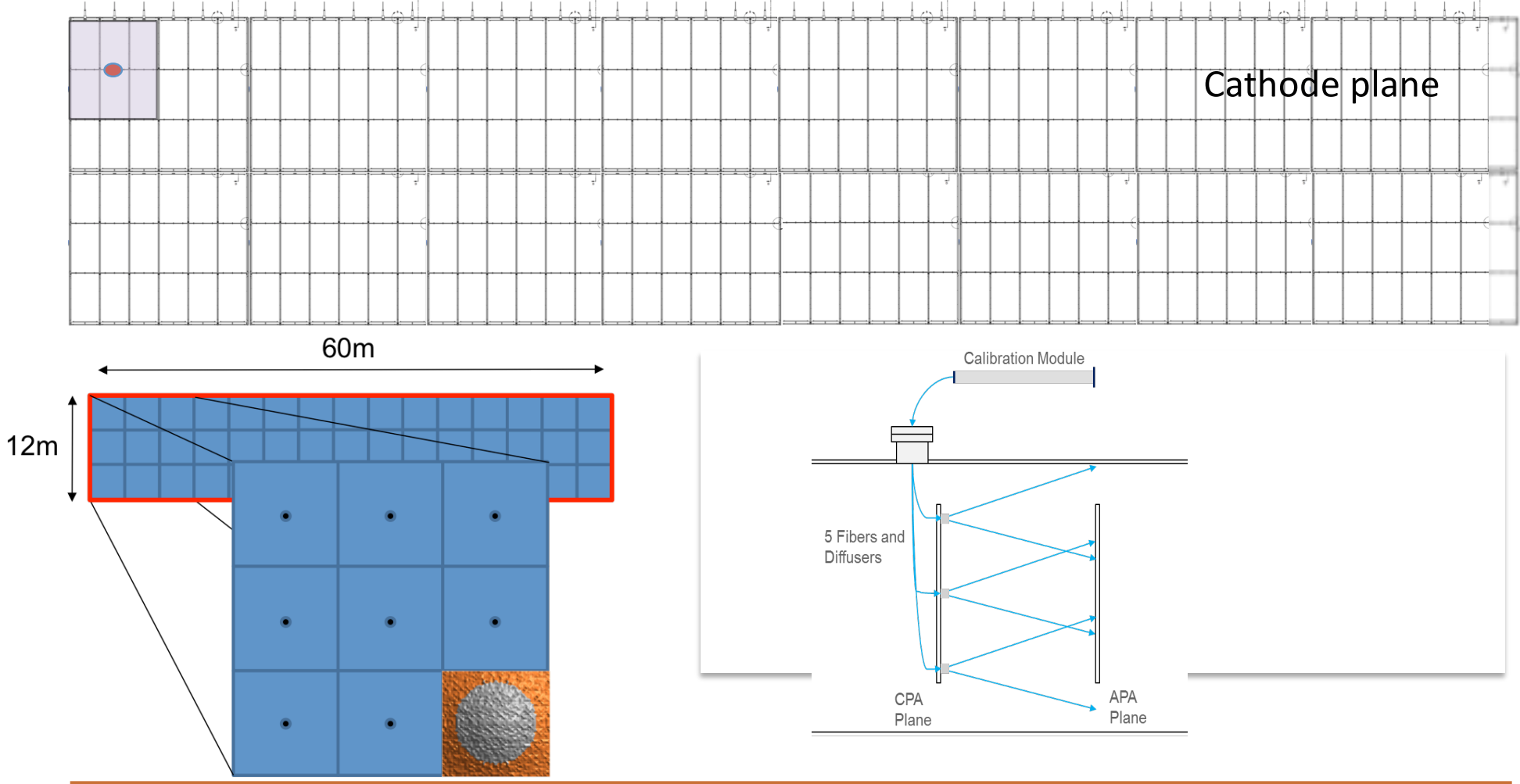


ARAPUCA Modules : Brazil  
 SiPMs & Summing : Italy, Spain  
 Readout : Peru, Columbia  
 Calibration : US DOE

Component	Description	Quantity
Light collector	X-ARAPUCA	10 modules per APA; 1500 total (1000 single-sided; 500 double-sided)
Photosensor	Hamamatsu MPPC 6 mm×6 mm *	192 SiPM per module; 288,000 total
SiPM signal summing	6 passive × 8 active	4 circuits per module; 6000 total
Readout electronics	Based on commercial ultrasound chip	4 channels/module; 6000 total
Calibration and monitoring	Pulsed UV via cathode-mounted diffusers	45 diffusers/CPA side; 180 total

\* FBK/Italy also being studied

# Photon Detector Monitoring





# Data Acquisition

UK

CERN

Data Selection scope  
(trigger) in NSF proposal

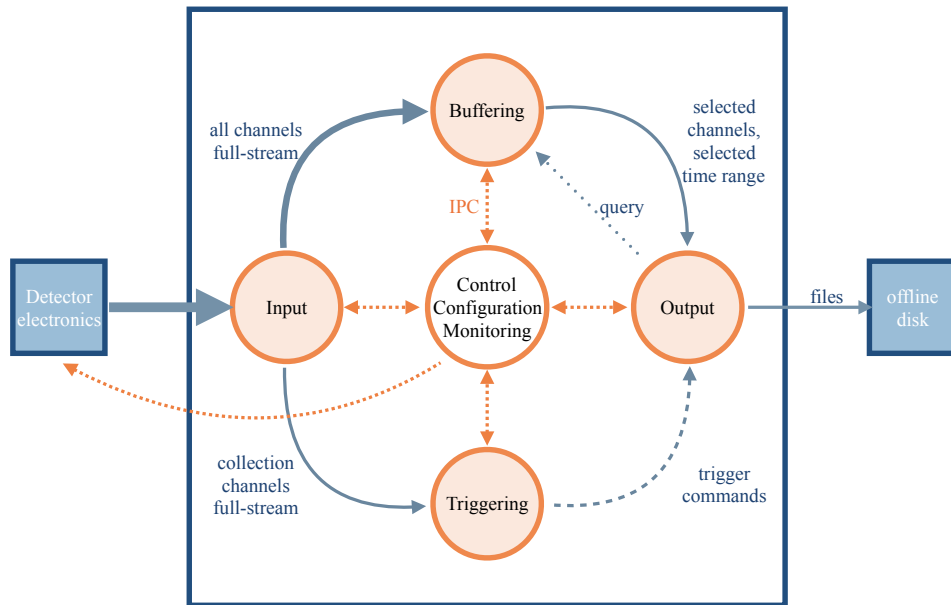
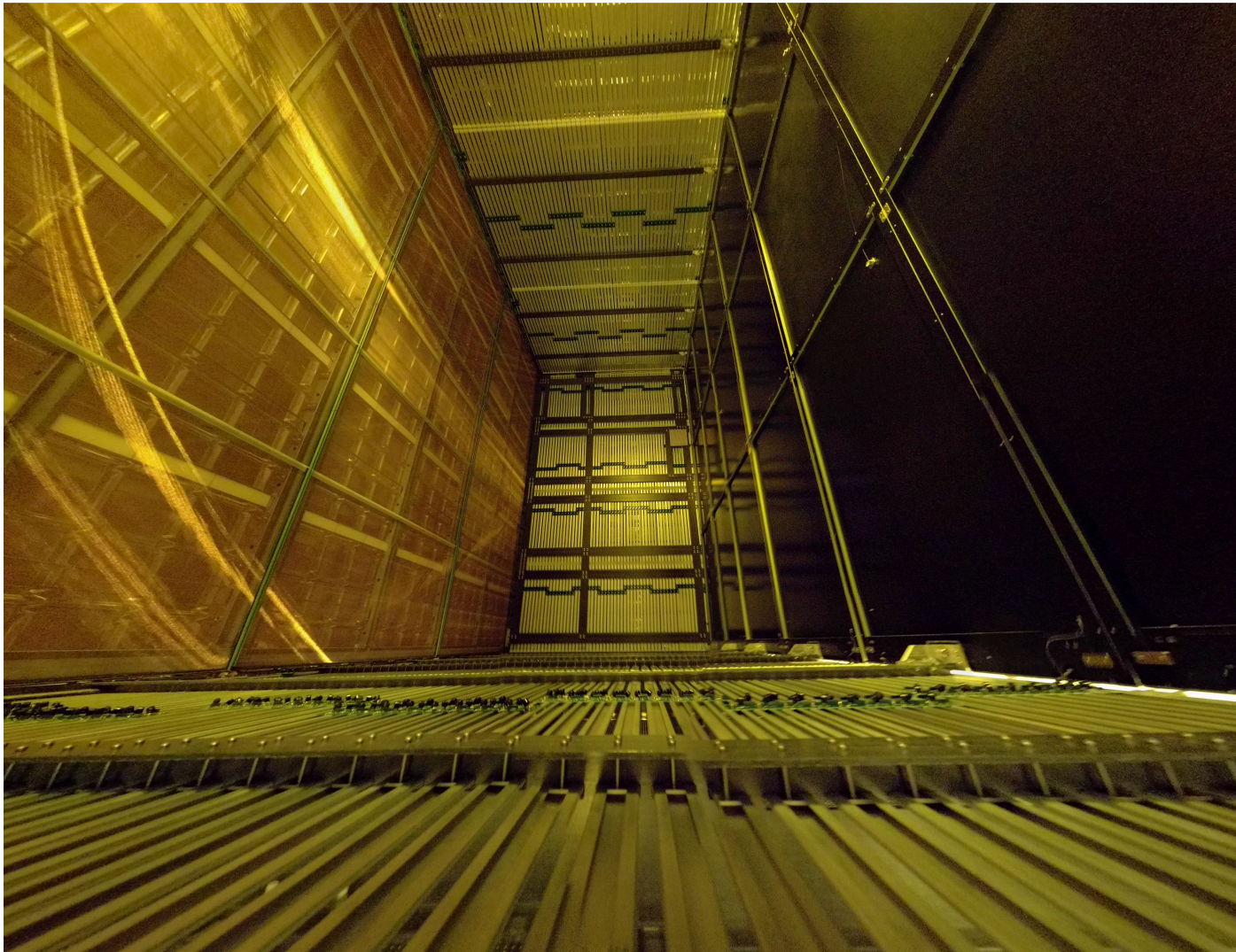


Figure 1.3: Conceptual Overview of DAQ System Functionality for a single 10 kt module

Each set of APA WIBs connects to one FELIX FPGA PCIe 3.0 board

- System requirements driven by need for
  - High uptime
  - Configurable and controllable from remote locations
  - Operational during installation and commissioning via separate partitions
  - Large buffering capability and low fake triggers for Supernova
  - Reduce data volume prior to off-line storage
- Five sub-systems
  - Upstream DAQ
  - Data selection
  - Back-end subsystem
  - Control, Configuration and Monitoring
  - Timing and synchronization

# The Single Phase TPC



- APA's + electronics, along with Photon Detectors, the High Voltage and Data Acquisition Systems comprise the essential elements of the Single Phase Detector.

# Instrumentation and Calibration

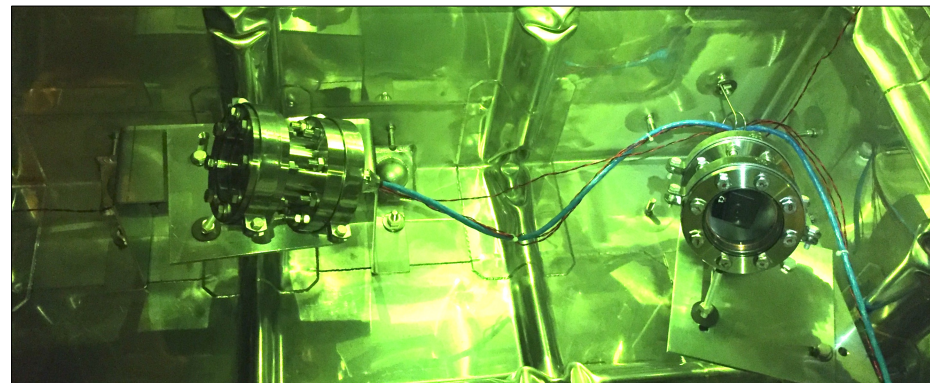
- Instrumentation includes :
  - Temperature probes
  - Level meters
  - Gas analyzers
  - Purity Monitors
  - Cameras
- Systems proposed :
  - Laser \*
  - Pulsed Neutron Source
  - Radioactive source

These systems had Scope reviews in June 2019; ProtoDUNE-II plans being developed

Static Temperature Probes to be provided by IFIC, Valencia

Currently no LBNF/DUNE Scope for Instrumentation or Calibration; may include small amount

Potential contributions from DUNE-US project funds or other funding sources (i.e. ECA)



\*Lasers are the most significant cost impact of these two areas

# DUNE Costing Model :

## International Responsibility Matrix

- Modeled after the CERN approach to quantify international contributions
  - Based on CORE accounting (direct M&S for capital investments)
    - No R&D, escalation, overheads, contingency
    - NO LABOR Costs, hours documented
- Here's where it get tricky : different approaches ...
  - Ability/desire to cover a specific scope (by %) -> \$ contribution to total CORE cost
  - Ability/desire to contribute a specific \$ amount
    - How much is available for M&S -> % contribution of CORE
  - Depending on the situation, developing the matrix needs to be an iterative process

# Status of Cost Estimates

- Single Phase
  - Cost Workbooks (CORE accounting : M&S plus Labor hours) either complete or nearing completion for all major systems
  - P6 accounting for DOE scope
  - 1<sup>st</sup> pass CORE accounting for 2 modules
    - Some systems more rigorous than others
- Dual Phase
  - Cost Workbook (in current format) for Photon Detectors
  - Cost estimate (older format) for Electronics
  - Cost estimate (top down) for CRPs
  - Cost estimates from SP-DP Joint consortia being developed
  - Preliminary 1<sup>st</sup> pass CORE accounting for 1 module coming soon
- Near Detector
  - Preliminary estimates for a minimum reference detector being developed

# Maturity of SP Estimates

- Cost estimates are prepared by the Consortia Technical Leaders
  - Technical Leads are also the L2 managers where there is DOE scope
  - We are trying to ensure that CORE costs and hours can be reconciled with the P6 costs; work in progress
- APAs, CE and HV based on actual costs from building ProtoDUNE
- DAQ based on costs of FELIX system in ATLAS; cost driver (but not CORE) is labor
- Photon system is new (Arapuca based); ProtoDUNE was strictly a development phase; SiPM cost is large, but under negotiation; readout being based on existing mu2e design to reduce cost from what was used for ProtoDUNE
- Instrumentation : material costs known from ProtoDUNE, labor is largely collaboration supplied
- Calibration : new system, scope under review, lasers are expensive; still studying technical feasibility of source calibration systems

# Consortia Cost Books

- Cost Books are posted in DUNE DocDB#14458
- In order of CORE Cost :
  - SP-APA\_Sept2019.xlsx : organization not finished after reorganizing for the NSF proposal; solid estimate with BOE's based on PD
  - SP-CE\_May2019.xlsx : good organization; BOEs based on PD
    - Update for DOE IPR in DocDB#10315 (open to ncg)
  - SP-PD\_May2019.xlsx : SiPM is cost driver; solid BOEs
  - SP-DAQ\_Aug2019.xlsx : good organization; based on recent experiences; M&S is higher than earlier planned, but solid; driver in this system is labor
  - SP-HV\_Sept2019.xlsx : good organization; based on PD but updated to accommodate design and assembly changes
  - SP-Cal\_July2019.xlsx : not very detailed; concentration on cost of big ticket items (lasers); system scope not finalized
  - SP-CISC\_May2019 : lots of smallish components here; not real cost driver

SP-PD\_May2019 Search Sheet

Home Insert Draw Page Layout Formulas Data Review View

Calibri (Body) 12 Currency

Share Comments

C13 fx =Light Collector Cost Book Detail!D57

	A	B	C	D	E	F	G	H	I	J	K
	WBS	WBS Element Name	M&S	Engineer	Designer	Tech	Student Tech	Grad-Student	Post-Doc	Faculty /Staff	
1	2.4	DUNE SP-PD (Single 10KT)	\$9,491,035	15,620	4,320	72,403	21,290	2,660	10,485	7,919	113,633
2	2.4.1*	Project Management (Milestones, Reviews)	\$0	220	0	0	0	880	880	880	
3	2.4.2*	Physics and Simulations	\$0	1960	0	0	0	0	2260	0	
4											
5	2.4.3	Design, Engineering and R&D	\$555,057	5860	2120	4020	2860	1260	2270	1630	
6	2.4.3.1	Light Collectors Design and Engineering	\$185,000	3040	0	1440	1120	0	0	880	
7	2.4.3.2	Photo Sensors Design and Engineering	\$175,000	880	500	1340	420	300	350	150	
8	2.4.3.3	Electronics, Cabling and Monitoring Design and Engineering	\$165,057	1360	940	880	1080	960	1460	280	
9	2.4.3.4	Integration and Installation Test Hardware Design and Engineering	\$30,000	580	680	360	240	0	460	320	
10											
11	2.4.4	Production Setup	\$498,117	2220	1160	3020	1480	840	360	790	7880
12	2.4.4.1	Light Collectors Production Setup	\$263,117	640	0	800	880	0	0	160	
13	2.4.4.2	Photo Sensors Production Setup	\$100,000	880	520	840	600	360	240	320	
14	2.4.4.3	Electronics, Cabling and Monitoring Production Setup	\$90,000	460	520	840	0	480	0	250	
15	2.4.4.4	Integration and Installation Test Hardware Production Setup	\$45,000	240	120	540	0	0	120	60	
16											
17	2.4.5	Production	\$8,387,862	6690	240	46738	16275	560	1280	2359	69943
18	2.4.5.1	Light Collector Production	\$3,134,179	1960	0	32575	1775	0	150	680	
19	2.4.5.2	Photo Sensors Production	\$3,978,480	3030	0	7320	14500	200	440	1280	
20	2.4.5.3	Electronics, Cabling and Monitoring Production	\$1,275,203	1700	240	6843	0	360	690	399	
21											
22	2.4.6	Integration and Installation	\$50,000	850	800	18625	675	0	6575	3140	20950
23											
24	*	not included in sums									98773
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WBS Dictionary Detailed Cost Book Rollup Management Cost Book Detail Phys & Sim Cost Book Detail Light Collector Cost Book Detail Light Collector BOE

Ready 100%



# Cost Book Detail

SP-PD\_May2019

Q- Search Sheet

Home Insert Draw Page Layout Formulas Data Review View

Calibri (Body) 12

General

Conditional Formatting Format as Table Cell Styles

Insert Delete Format

Sort & Filter Find & Select

Share Comments

O92

COMPLETE LIST OF BOE DOCUMENTS IN DOCS& XXXX. ITEMS IN GREEN ARE INCLUDED IN THE LOCAL "LIGHT COLLECTOR BOE" TAB

	MIS	Engineer	Designer	Tech	Student Tech	Grad Student	Post-Doc	Faculty/Staff
Light Collector Design and Engineering	185000	3040		1440	1120			880
2.4.3.1.1 Light Collector Module	150000	1920	960	640	160			
DESCRIPTION: Final post-TDR Light Collector Module Engineering, Design and Validation								
	Unit	Price/unit	No. req'd	No. Total	Total price	Method of Estimate	Estimate quality (M&S)	BOE
								Mech. Engineer Support
								Hrs./unit Number Total hours
								Mech. Technician
								Hrs./unit Number Total
2.4.3.1.1.1 ARAPUCA- Design								480 1 480 240 1
2.4.3.1.1.2 ARAPUCA-Engineering Design								480 1 480 240 1
2.4.3.1.1.3 ARAPUCA-Materials Testing/Verification	Lot	50000	1	1	50000	EE	4	480 1 480 240 1
2.4.3.1.1.4 ARAPUCA-ProtoDUNE-2 (30 modules)	Lot	100000	1	1	100000	EE	4	480 1 480 240 1
TOTALS					150000			1920
2.4.3.1.2 Final Production Preparation	35000	1120	480	480	720			
DESCRIPTION: Final testing of pre-productive prototypes before pre-production review								
	Unit	Price/unit	No. req'd	No. Total	Total price	Method of Estimate	Estimate quality (M&S)	BOE
								Mech. Engineer Support
								Hrs./unit Number Total hours
								Mech. Technician
								Hrs./unit Number Total
2.4.3.1.2.1 Testing of PD Module Prototypes	Lot	35000	1	1	35000	EE	3	320 1 320 320 1
2.4.3.1.2.2 System Configuration Final Selection								320 1 320 1
2.4.3.1.2.3 Final Engineering Design								480 1 480 160 1
TOTALS					35000			1120
Light Collector Production Setup	263116.76	640	0	800	880			160

WBS Dictionary Detailed Cost Book Rollup Management Cost Book Detail Phys & Sim Cost Book Detail Light Collector Cost Book Detail Light Collector BOE

Ready 76%

# BOE Documentation

SP-PD\_May2019

Home Insert Draw Page Layout Formulas Data Review View

Calibri (Body) 12

General

E81

**NOTE: QUOTES/ESTIMATES ARE NOT FINAL AND VETTED. FOR DISCUSSION ONLY!**

Eijen WLS Plate VE

Dichroic Filter VE

Cor

50%

**EJEN TECHNOLOGY**  
 1300 W. Broadway  
 Houston TX 77058  
 USA  
 Voice: (281) 238-4276 or (888) 888-4771  
 Fax: (281) 238-4791  
 Website: www.ejentechnology.com

**QUOTATION**

Quote Number: 2019-007A  
 Please refer to Quote Number when referring to quote.

Quote Date: 24-Apr-19

Page: 1

Request for Proposal: David Warner

Quoted To:  
 COLORADO STATE UNIVERSITY  
 Physics Department  
 Attn: David Warner, Ph.D.  
 Email: David.Warner@colorado.edu

In response to your request, we are pleased to offer the following items:

Payment Terms	Shipping Method	FOB	Validity of Quote	Delivery
NET 30 Days	FedEx Express	Destination	90 days	18-24 months

\*Lead times are based on our current workload. A firm delivery date will be provided at the time of the order.

Item	Qty	Description	Unit Price USD	Total Price USD
1	6,000	EJ-258 Blawhuffing plastic 400µm Size: 3.5mm (dia) x 0.15mm x 488.0mm Faces clear as-cast optical glass and edges diamond-milled Length and width tolerance: ±0.035mm Thickness tolerance: ± 0.25mm	\$129.50	\$777,800.00

Sub Total: \$777,800.00  
 Sales Tax  
 Wire Trans  
 Free (J&H)  
 TOTAL: \$777,800.00

Bank To: Wire Transfer / Bank Details  
 Ejen Technology: JP Morgan Chase Bank - Dallas Texas  
 250 Ross Street  
 Dallas TX 75202-2965  
 USA  
 Account Name: Ejen Technology  
 Account No: 635502007

Country of Origin: USA

By: Charles Hurlbut

**opto**  
 Science in Sight

- **Substrato do Filtro:** Vidro Ótico de alta transparência com as seguintes características:

- Transmittância  $\nu$ D65 ( $d = 2.0 \text{ mm}$ ) = 91.7%
- Coeficiente de expansão (20 °C; 300 °C) (static measurement) =  $9.4 \cdot 10^{-6} \text{ K}^{-1}$
- Temperatura de "melting" = Tg542 °C
- Dielectric constant Dielétrica at 1 MHz = 7.5
- Índice de Refração  $n_D = 1.5229$
- Densidade = 2.56 g/cm<sup>3</sup>

- **Dimensões do Filtro:** 80 x 100 +/- 0,1mm com espessura 1,0 +/- 0,1mm

- **Embalagem:** os filtros serão acondicionados em caixas de vacum-form com 20 (vinte) peças por caixa, fechadas, colocadas dentro de sacos plásticos selados. Os filtros estarão dispostos cerca de 10mm um do outro o que facilitará o manuseio e manterá a limpeza dos filtros. Essas caixas especiais com os filtros serão então acondicionadas em caixas de papelão protegidas internamente com isopor (12 caixas de filtros por caixa de papelão – o que oferece proteção para os filtros contra choques mecânicos). A Opto se responsabilizará por desenvolver e produzir a embalagem. A critério do cliente a embalagem poderá ser reciclável.

**Proposta Comercial:**

- Quantidade Orçada: 48.000 (48mil) peças.
- Preço Unitário: **R\$ 164,87 + 15% IPI**
- Impostos incluídos no Preço

WBS Dictionary Detailed Cost Book Rollup Management Cost Book Detail Phys & Sim Cost Book Detail Light Collector Cost Book Detail Light Collector BOE

# Cost Book Rollup

WBS	WBS Element Name	M&S	Engineer	Designer	Tech	Student Tech	Grad-Student	Post-Doc	Faculty /Staff
2.4	DUNE SP-PD (Single 10KT)	\$9,491,035	15,620	4,320	72,403	21,290	2,660	10,485	7,919
2.4.1*	Project Management (Milestones, Reviews)	\$0	220	0	0	0	880	880	880
2.4.2*	Physics and Simulations	\$0	1960	0	0	0	0	2260	0
2.4.3	Design, Engineering and R&D	\$555,057	5860	2120	4020	2860	1260	2270	1630
2.4.3.1	Light Collectors Design and Engineering	\$185,000	3040	0	1440	1120	0	0	880
2.4.3.2	Photo Sensors Design and Engineering	\$175,000	880	500	1340	420	300	350	150
2.4.3.3	Electronics, Cabling and Monitoring Design and Engineering	\$165,057	1360	940	880	1080	960	1460	280
2.4.3.4	Integration and Installation Test Hardware Design and Engineering	\$30,000	580	680	360	240	0	460	320
2.4.4	Production Setup	\$498,117	2220	1160	3020	1480	840	360	790
2.4.4.1	Light Collectors Production Setup	\$263,117	640	0	800	880	0	0	160
2.4.4.2	Photo Sensors Production Setup	\$100,000	880	520	840	600	360	240	320
2.4.4.3	Electronics, Cabling and Monitoring Production Setup	\$90,000	460	520	840	0	480	0	250
2.4.4.4	Integration and Installation Test Hardware Production Setup	\$45,000	240	120	540	0	0	120	60
2.4.5	Production	\$8,387,862	6690	240	46738	16275	560	1280	2359
2.4.5.1	Light Collector Production	\$3,134,179	1960	0	32575	1775	0	150	680
2.4.5.2	Photo Sensors Production	\$3,978,480	3030	0	7320	14500	200	440	1280
2.4.5.3	Electronics, Cabling and Monitoring Production	\$1,275,203	1700	240	6843	0	360	690	399
2.4.6	Integration and Installation	\$50,000	850	800	18625	675	0	6575	3140

\* not included in sums

# SP-Master\_Oct2019.xlsx

Snapshot – 10/01/19

WBS	WBS Element Name	M&S	Engineer	Designer	Tech	Student	GS	Post-Doc	Scientist
<b>2</b>	<b>DUNE SP Far Detector</b>	<b>\$105,000,670</b>	<b>170,631</b>	<b>4,474</b>	<b>442,180</b>	<b>120,838</b>	<b>268,130</b>	<b>252,677</b>	<b>151,290</b>
# of modules	2								
<b>2.2</b>	<b>SP APA System (SP-APA)</b>	<b>\$29,417,102</b>	<b>69,571</b>	<b>0</b>	<b>205,918</b>	<b>0</b>	<b>129,040</b>	<b>3,772</b>	<b>1,840</b>
2.2.4	Production Setup	\$4,219,422	7,042	-	1,992	-	4,240	-	-
2.2.5	Production	\$25,197,680	61,908	-	203,044	-	112,640	-	-
2.2.6	Integration and Installation	\$0	621	-	882	-	12,160	3,772	1,840
<b>2.3</b>	<b>SP TPC Electronics System (SP-CE)</b>	<b>\$26,283,696</b>	<b>17,915</b>	<b>1,020</b>	<b>34,032</b>	<b>44,992</b>	<b>24,064</b>	<b>49,339</b>	<b>19,040</b>
2.3.4	Production Setup	\$2,001,371	6095	1020	1374	2284	620	2981	2540
2.3.5	Production	\$24,237,801	3320	0	8658	42708	900	11758	0
2.3.6	Integration and Installation	\$44,524	8500	0	24000	0	22544	34600	16500
<b>2.4</b>	<b>SP Photon Detection System (SP-PD)</b>	<b>\$17,373,840</b>	<b>15,720</b>	<b>2,080</b>	<b>131,525</b>	<b>34,780</b>	<b>1,120</b>	<b>15,710</b>	<b>11,158</b>
2.4.4	Production Setup	\$498,117	640	-	800	880	-	-	160
2.4.5	Production	\$16,775,723	13,380	480	93,475	32,550	1,120	2,560	4,718
2.4.6	Integration and Installation	\$100,000	1,700	1,600	37,250	1,350	-	13,150	6,280
<b>2.8</b>	<b>SP HV System (SP-HV)</b>	<b>\$10,643,310</b>	<b>2,842</b>	<b>1,374</b>	<b>31,849</b>	<b>41,066</b>	<b>13,427</b>	<b>12,528</b>	<b>14,193</b>
2.8.4	Production Setup	\$163,000	432	250	2463	457	180	200	808
2.8.5	Production	\$10,468,310	2410	660	29386	28305	13247	11800	7753
2.8.6	Integration and Installation	\$12,000	0	464	0	12304	0	528	5632
<b>2.9</b>	<b>SP DAQ System (SP-DAQ)</b>	<b>\$14,772,000</b>	<b>38,984</b>	<b>0</b>	<b>25,427</b>	<b>0</b>	<b>45,760</b>	<b>97,856</b>	<b>51,040</b>
2.9.4	Production Setup	\$0	-	-	-	-	-	-	-
2.9.5	Production	\$14,552,696	28864	0	25427	0	45760	97856	15840
2.9.6	Integration and Installation	\$220,000	10120	0	0	0	0	0	35200
<b>2.10</b>	<b>SP Cryo Inst and Slow Control (SP-CISC)</b>	<b>\$2,307,068</b>	<b>1731</b>	<b>0</b>	<b>6356</b>	<b>0</b>	<b>22896</b>	<b>23968</b>	<b>19013</b>
2.11.4	Production Setup	\$6,706	661	0	1321	0	2917	7868	6542
2.11.5	Production	\$2,126,482	589	0	3042	0	10608	4490	6460
2.11.6	Integration and Installation	\$173,880	480	0	1993	0	9370	11610	6011
<b>2.11</b>	<b>SP Calibration Systems (SP-Cal)</b>	<b>\$4,203,654</b>	<b>23868</b>	<b>0</b>	<b>7072</b>	<b>0</b>	<b>31824</b>	<b>49504</b>	<b>35006.4</b>
2.11.4	Production Setup								
2.11.5	Production	\$4,203,654	23,868	-	7,072	-	31,824	49,504	35,006
2.11.6	Integration and Installation								

# CORE Cost

Snapshot – 10/01/19

WBS	WBS Element Name	M&S	Engineer	Designer	Tech	Student	GS	Post-Doc	Scientist
<b>2</b>	<b>DUNE SP Far Detector</b>	<b>\$105,000,670</b>	<b>170,631</b>	<b>4,474</b>	<b>442,180</b>	<b>120,838</b>	<b>268,130</b>	<b>252,677</b>	<b>151,290</b>
# of modules	2								
<b>2.2</b>	<b>SP APA System (SP-APA)</b>	<b>\$29,417,102</b>	<b>69,571</b>	<b>0</b>	<b>205,918</b>	<b>0</b>	<b>129,040</b>	<b>3,772</b>	<b>1,840</b>
2.2.4	Production Setup	\$4,219,422	7,042	-	1,992	-	4,240	-	-
2.2.5	Production	\$25,197,680	61,908	-	203,044	-	112,640	-	-
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<b>2.3</b>	<b>SP TPC Electronics System (SP-CE)</b>	<b>\$26,283,696</b>	<b>17,915</b>	<b>1,020</b>	<b>34,032</b>	<b>44,992</b>	<b>24,064</b>	<b>49,339</b>	<b>19,040</b>
2.3.4	Production Setup	\$2,001,371	6095	1020	1374	2284	620	2981	2540
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2.8.4	Production Setup	\$163,000	432	250	2463	457	180	200	808
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<b>2.9</b>	<b>SP DAQ System (SP-DAQ)</b>	<b>\$14,772,000</b>	<b>38,984</b>	<b>0</b>	<b>25,427</b>	<b>0</b>	<b>45,760</b>	<b>97,856</b>	<b>51,040</b>
2.9.4	Production Setup	\$0	-	-	-	-	-	-	-
2.9.5	Production	\$14,552,696	28864	0	25427	0	45760	97856	15840
2.9.6	Integration and Installation	\$220,000	10120	0	0	0	0	0	35200
<b>2.10</b>	<b>SP Cryo Inst and Slow Control (SP-CIS)</b>	<b>\$2,307,068</b>	<b>1731</b>	<b>0</b>	<b>6356</b>	<b>0</b>	<b>22896</b>	<b>23968</b>	<b>19013</b>
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<b>2.11</b>	<b>SP Calibration Systems (SP-Cal)</b>	<b>\$4,203,654</b>	<b>23868</b>	<b>0</b>	<b>7072</b>	<b>0</b>	<b>31824</b>	<b>49504</b>	<b>35006.4</b>
2.11.4	Production Setup								
2.11.5	Production	\$4,203,654	23,868	-	7,072	-	31,824	49,504	35,006
2.11.6	Integration and Installation								

# Responsibility Matrix

Snapshot – 10/01/19

Preliminary and Confidential – for example only

We can discuss the one with real numbers when we have the presentation

2 Single Phase Modules											
Responsibility Matrix	Total	US DOE	US NSF	UK	Brazil	Italy	CERN	Canada	Spain	Portugal	Opportunity
SP TPC Electronics System (SP-CE)	100%	100%									
SP APA System (SP-APA)	100%		50%	50%							
SP Photon Detection System (SP-PD)	100%	10%									24%
SP HV System (SP-HV)	100%	40%									45%
SP DAQ System (SP-DAQ)	100%		18%	32%							34%
SP Cryo Inst and Slow Control (SP-CISC)	100%	10%									82%
SP Calibration Systems (SP-CAL)	100%	10%									80%

Money Matrix	Total - CORE	US DOE	US NSF	UK	Brazil	Italy	CERN	Canada	Spain	Portugal	Opportunity
SP TPC Electronics System (SP-CE)	\$ 26.28	\$ 26.28	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
SP APA System (SP-APA)	\$ 29.42	\$ -	\$ 14.71	\$ 14.71	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
SP Photon Detection System (SP-PD)	\$ 17.37	\$ 1.65	\$ -	\$ -			\$ -	\$ -		\$ -	\$ 4.08
SP HV System (SP-HV)	\$ 10.64	\$ 4.20	\$ -	\$ -	\$ -	\$ -		\$ -	\$ -	\$ -	\$ 4.74
SP DAQ System (SP-DAQ)	\$ 14.77	\$ -	\$ 2.59	\$ 4.67	\$ -	\$ -			\$ -	\$ -	\$ 4.98
SP Cryo Inst and Slow Control (SP-CISC)	\$ 2.31	\$ 0.23	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -		\$ -	\$ 1.90
SP Calibration Systems (SP-CAL)	\$ 4.20	\$ 0.42	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -		\$ 3.36
Total contibution to M&S	\$ 105.00	\$ 32.79	\$ 17.29	\$ 19.38							\$ 19.06
% of Total M&S		31%	16%	18%							18%

Common Fund for CORE Contribution	20%	\$ 6.6	\$ 3.5	\$ 3.9							\$ 3.8
From DOE	\$ 10.0	covers DOE and NSF contribution									
From International Partners	\$ 11.0	includes contribution from "Opportunity"									

	Color code	Detectors
Agreements in place or funding secured		43%
Proposals under review		22%
Proposals in preparation		0%
Aspirational/beginning discussions		1%
Opportunity or Scope Reduction		34%
Total CORE M&S		100%

# Next Steps

- Near Term (6 months)
  - Complete APA Cost Book and update summary tables if necessary
  - DOE IPR : October 30 – Nov 1, 2019
  - DOE DUNE Operations Review : January 6-7, 2020
    - **Costs for Technical Coordination and I&I**
  - Formalize responsibility for deliverables via Consortia Annexes for **Multi-institutional MOU** which is in draft status
  - Present **Common Fund Plan** at April RRB Meeting
  - Update Single Phase Cost Books in advance of DOE CD2/3 review in Spring 2020
- Longer Term
  - Form consortia and develop cost estimates and funding model for Near Detector systems
  - Develop bottoms up cost estimate and funding model for a Dual Phase module